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(54) Respiration monitor

(57) A respiration monitor of particular use in detecting infant apnea comprises, in one embodiment, a flexible, substantially laminar pad comprising a plurality of strip-like elements 6 of piezoelectric material having a metallic coating on opposite faces, the elements being spaced apart from one another and held between electrically insulating layers. To give protection against the generation of spurious electrical signals, a screening arrangement comprising an envelope formed of electrically conductive material such as a metallised plastics is provided which encapsulates the piezoelectric strips and electrical connections 4,8 to their opposite faces. Foam layers 3 may be applied to both sides of the pad. Another embodiment of the monitor comprises a probe for attachment to the skin of a patient in which a strip of piezoelectric film is folded into a U-shaped configuration, and both limbs of the film are separated by and also held between layers of electrically insulating material.

Fig.5.

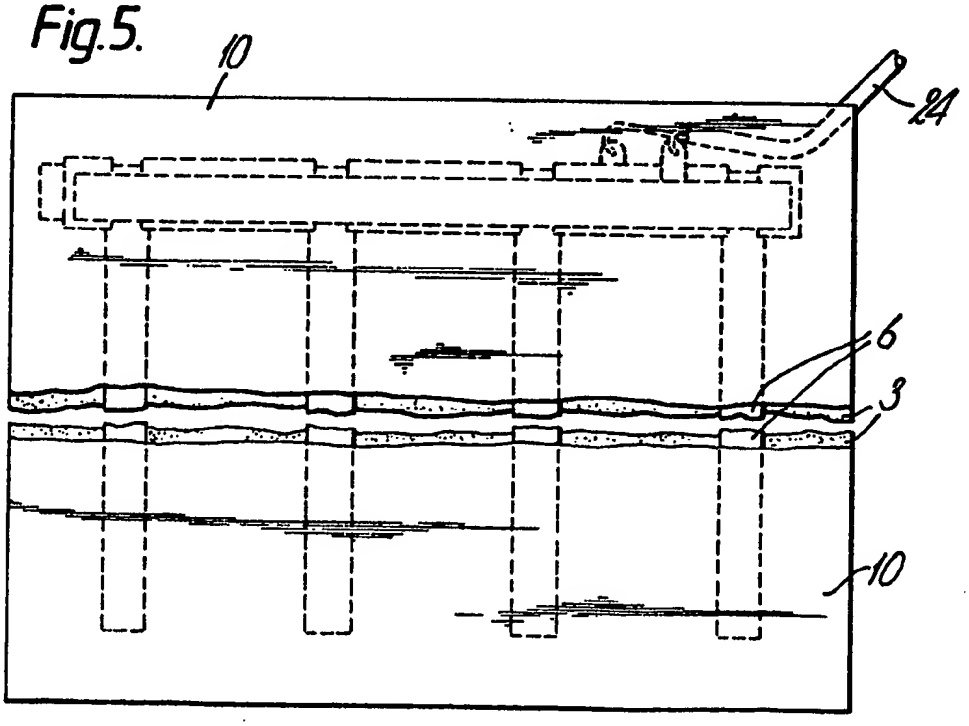

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Fig.1.

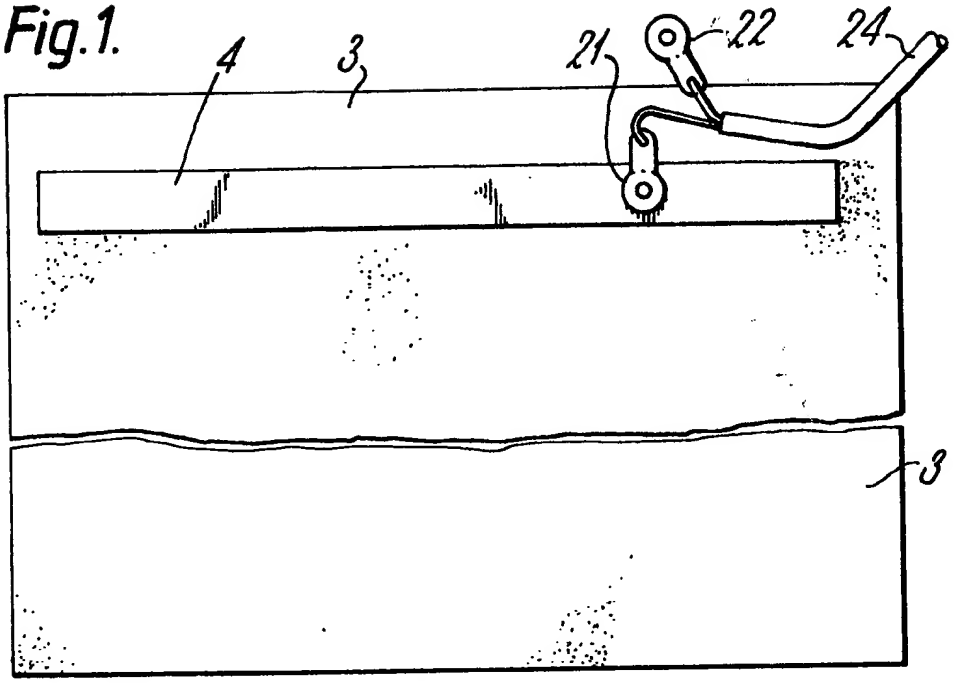


Fig.2.

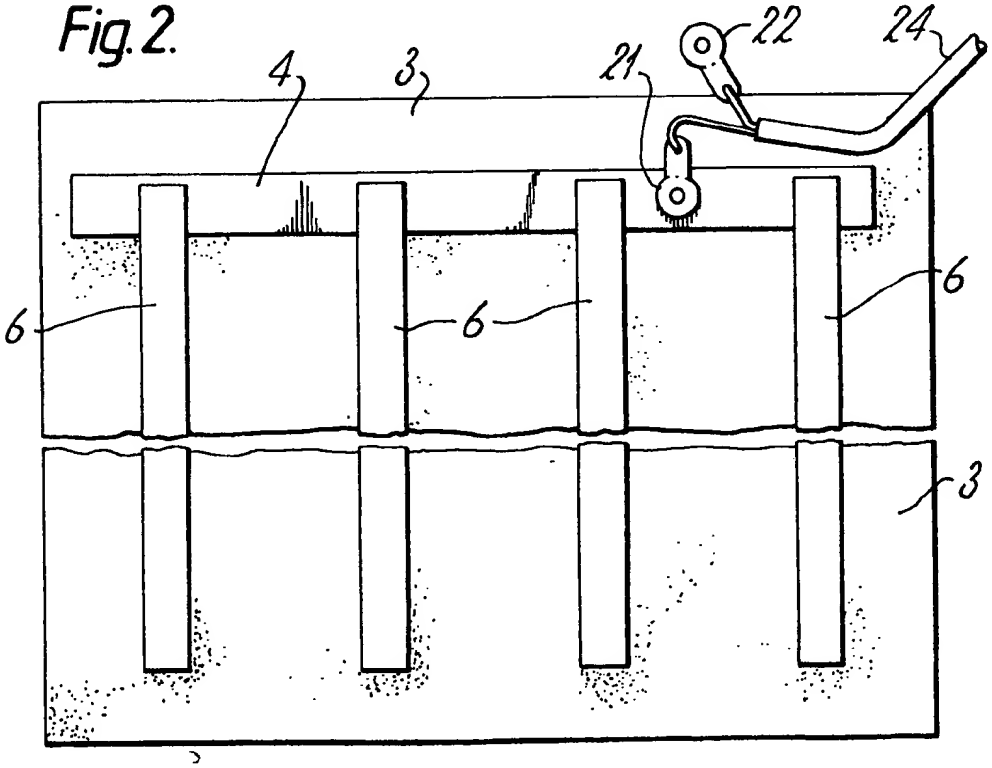


Fig. 3.

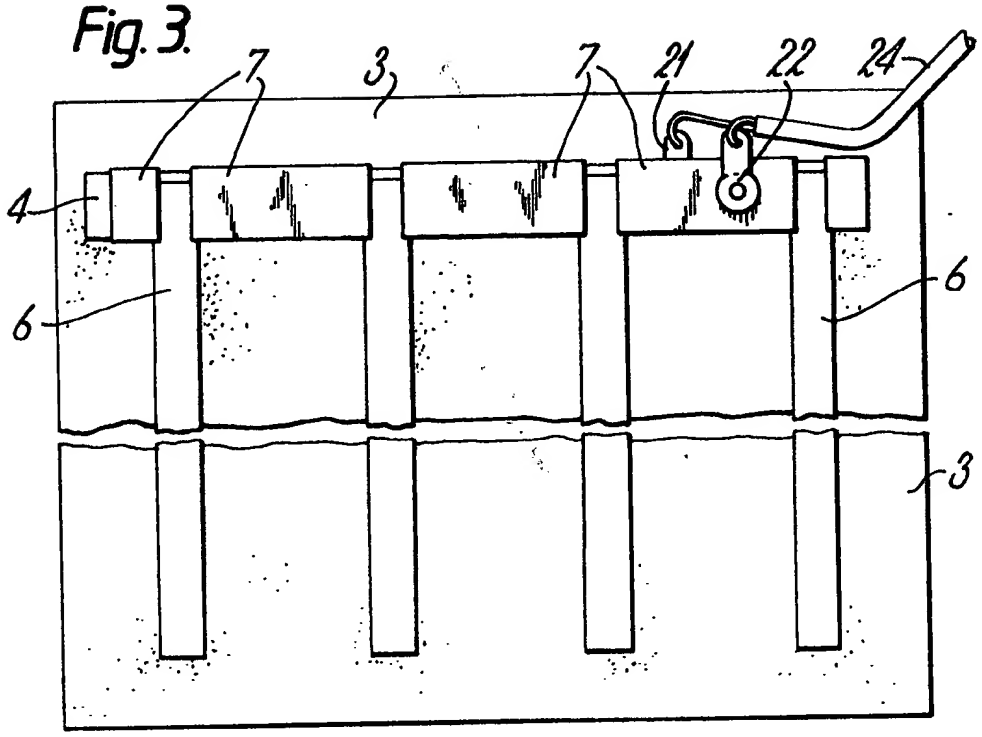


Fig. 4.

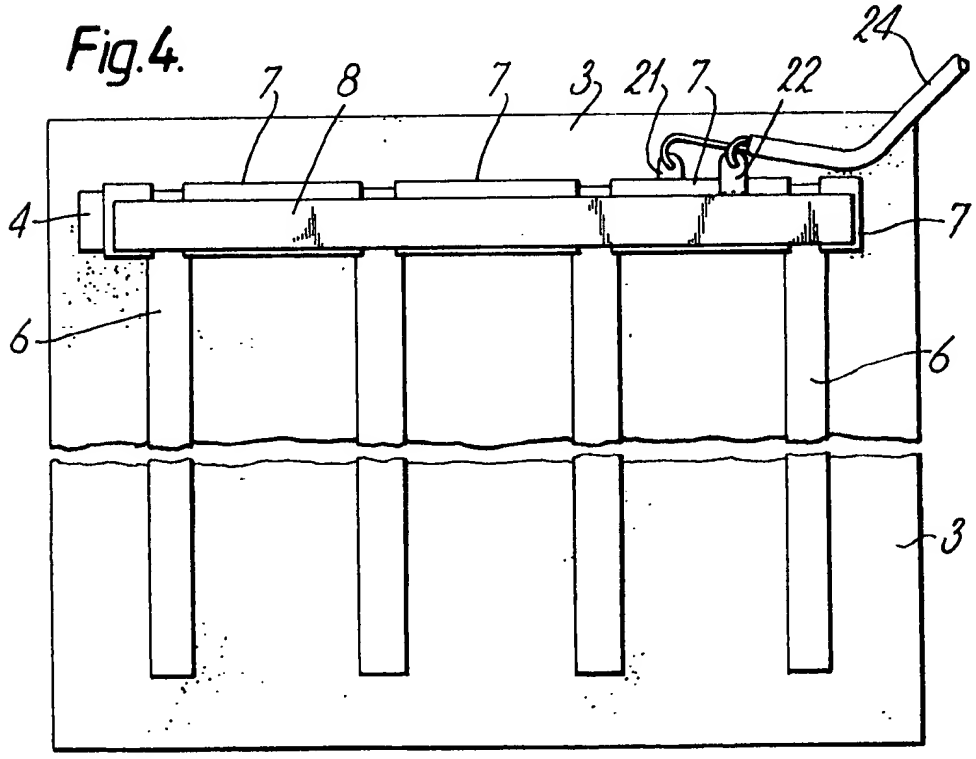
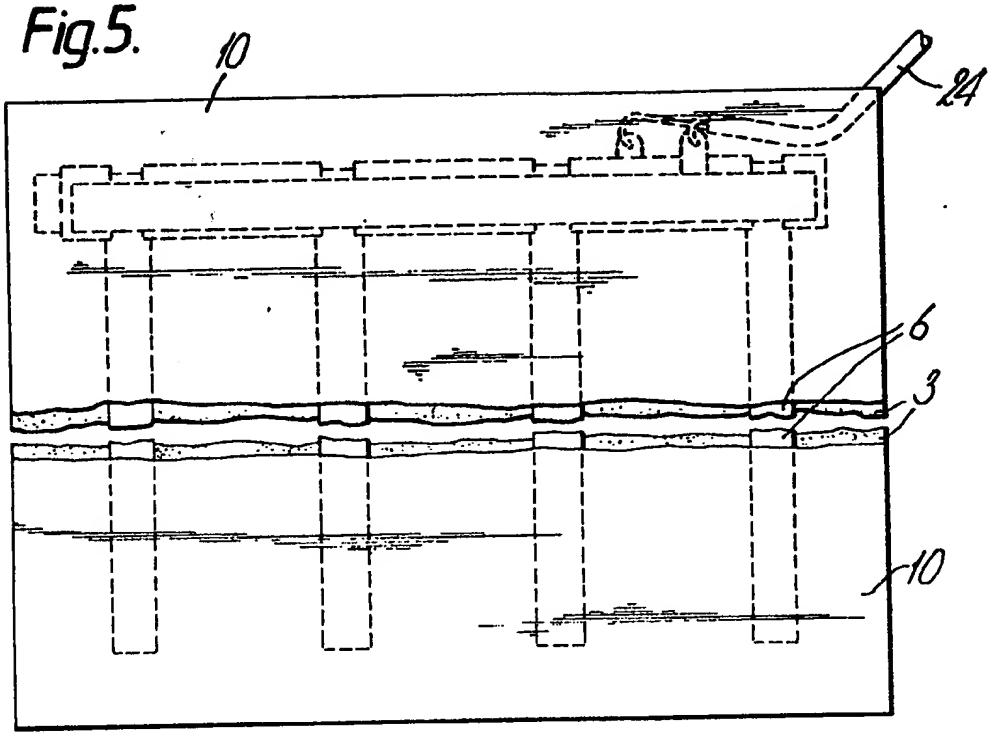


Fig.5.



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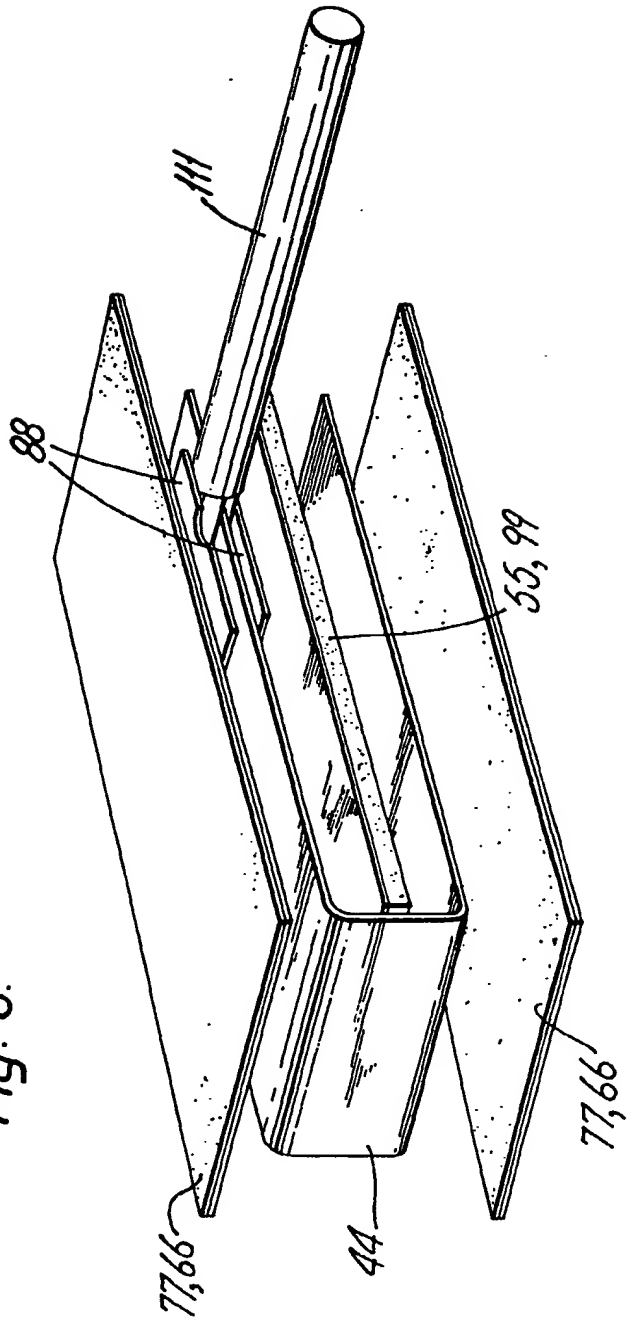

Fig. 6.

SPECIFICATION

Respiration monitor

This invention relates to a respiration monitor in particular of the type used to detect cessation of breathing in infants (infant apnea). Several monitors for detecting respiration, heartbeat or changes in body shape have been described. Some, for example those described in U.K. patent specifications 2048485A and 1,261,357, operate pneumatically. Others involve the use of a capacitor transducer (for example as disclosed in U.K. patent specification No. 1,336,488).

Materials such as polyvinylidene fluoride (PVDF), when suitably treated, are known to exhibit piezoelectric properties. A thin film of such a material may be used to detect movements of the human body wall. By analysing the piezoelectric signals generated by the film, it is possible to determine heart rate, respiratory rate and other factors which are of value in the understanding of physiological processes.

The apparatus used to analyse the signals generated by respiration monitors can take various forms and do not of themselves constitute a part of the present invention.

According to one aspect of the present invention, there is provided a respiration monitor which is in the form of a flexible, substantially laminar pad and which comprises a plurality of strip-like elements of a piezoelectric film having a metallic coating on both faces thereof, said elements being spaced apart from one another and held between two layers of an electrically insulating material; an electrical screening arrangement for preventing or reducing the generation of spurious electrical signals in said elements; and electrical conductors for conveying piezoelectric signals generated by said elements to the exterior of the respiration monitor. We have found that the use of a plurality of strips of piezoelectric film is particularly advantageious in that a high response to patient movement is achieved.

Advantageously the monitor includes at least one layer of a thin plastics foam material—e.g. PVC foam about 1 to 2mm in thickness. The piezoelectric elements are spaced from one another and can be arranged in a side-by-side configuration. Other arrangements may be adopted if desired. The elements can be sandwiched, at one end, between electrically conductive foils which are insulated from one another in the regi ns between the piezoelectric elements. Such foils provide electrical connections between the respective upper faces of the piez electric strips and the respective lower faces f the strips. A single electrical connection can thus be made to each of the foils in order to provide the electrical utput from th monitor.

With a pad-type monitor, we have found it essential to provide electrical screening in order to prevent the generation of spurious electrical signals. These can arise due to static effects, e.g. when a charged surface is brought into proximity with the monitor, or due to radio frequency interference. Preferably the piezoelectric elements and associated electrically conductive parts of the monitor are enclosed in an envelope formed of an electrically conductive material—e.g. a metallised plastics envelope—which is electrically insulated from the piezoelectric elements and associated electrically conductive parts. Such a screening arrangement, is essentially an external screen. Alternatively, but less preferably, screening can be incorporated into the monitor so as to be in physical contact (but not electrical contact) with the elements themselves.

Conveniently, the monitor can be fabricated to be rectangular in form, with sides of about 15cm by 25cm.

The piezoelectric elements and their associated parts are advantageously overlaid with a thin sheet of an electrically insulating material, e.g. a polyurethane film. Above this there is preferably a second layer of a foamed plastics material. The whole structure is advantageously housed in a bag or envelope formed, for example, of a plastics material such as PVC.

According to a second aspect of the present invention, there is provided a respiration monitor which is in the form of a substantially laminar, flexible pad and which comprises a layerwise arrangement: (1) a first layer of foam; (2) a first transverse electrically conductive strip secured to said first layer of foam close to one edge thereof; (3) a plurality of strip-like longitudinal elements of a piezoelectric film each secured, at one of their ends, to said first electrically conductive strip and to said first layer of foam and spaced apart from one another; (4) segments of an electrically insulating tape or foil extending between adjacent elements of piezoelectric film so as to overlie said first electrically conductive strip and so as to overlap the edges of said elements of piezoelectric film (5) a second transverse electrically conductive strip positioned so as to overlie said segments of insulating foil or tape; (6) a first electrical connector attached to said first electrically conductive strip and disposed between said first strip and one of the segments of insulating foil or tape; (7) a second electrical connector positioned between one of said segments f electrically insulating foil or tape and said second electrically conductive strip and attached t said second electrically conductive strip; (8) a screening arrangement for preventing or reducing the g neration of spurious electrical signals in said piezoelectric elements; (9) a second layer of foam; and (10) an envelope surrounding the other parts of the monit r, the arrangement being such that the two layers f f am hold between them integers (2) to (7) as

set forth above; and said envelope having an outlet for an electrical cable the electrically conductive cores of which are attached to a respective one of said first and second electrical connectors. connectors.

Advantageously, the screening arrangement adopted in the monitor defined above includes an envelope which is electrically conducting or has a coating or layer which is electrically conducting. A suitable material is an envelope formed of an aluminised polyester material.

The strip-like elements of piezoelectric film are preferably polyvinylidene fluoride. The first and second transverse electrically conductive strips are preferably copper tape. The layers of foam are conveniently foamed polyvinylchloride. The outer envelope surrounding the operative elements of the monitor is conveniently a PVC bag.

According to a third aspect of the present invention, there is provided a respiration monitor in the form of a probe for attachment to the skin of a patient, which monitor comprises a piezoelectric film having electrical connections on opposed surface portions thereof, said film being held between layers of electrically insulating material.

Advantageously, the piezoelectric film is folded over onto itself in the form of a "U" and is provided with a layer of insulating foam (e.g. foam PVC) in the space between the limbs of the "U".

The invention will be described further with reference to the accompanying drawings, in which Figs. 1–6 illustrate the assembly of a preferred embodiment of the pad-type respiration monitor and Fig. 7 illustrates the probe-type respiration monitor.

Referring now to Figs. 1 to 6 of the drawings, the monitor is in the form of a flexible pad comprising an outer bag or envelope formed of PVC (not shown). A cable 24 passes through the envelope at one corner thereof. The elements within this envelope are built up layerwise as illustrated in the drawings. The lowest layer is a layer 3 of PVC foam. This is a flat, spongy layer of about 1.5 mm in thickness. A screening envelope formed of aluminised polyester (not shown) is secured above the foam layer 3 and contains the operative parts of the monitor. Before the screening envelope is sealed, the operative parts of the monitor are built up layerwise, as will now be described. A first transverse electrically conductive strip 4 is secured across the screening close to the top edge thereof and is in electrical contact with the metallised outer surface there f. A first electrical connect r 21 makes electrical contact with strip 4. Four parallel strips 6 of piezoelectric polyvinylidene fluoride film about 10 microns in thickness are secured to the ends of elements 5 and to conductive strip 4 in the manner shown in Fig. 3. These strips, which are identical and may be in the range from 5 to 10mm in width, have metallised (.g. aluminised) surfaces. The strips may be cut from commercially available piezoelectric PVDF sheets, e.g. those sold by Yarsley Research Laboratories. Segments 7 of an electrically insulating material (e.g. PVC or polyester film) are positioned over the gaps between adjacent strips 6 so as to overlap their edges and to cover those parts of transverse electrically conductive strip 4 between adjacent strips 6. A second electrical connector 22 is adjacent to one of the segments 7, as shown in Fig. 4.

A second transverse electrically conductive strip 8 overlies the insulating segments 7 and the second electrical connector 22. As shown in Fig. 5, the second conductive strip 8 does not make direct electrical contact with the first strip 4. In the illustrated arrangement, strip 4 is maintained at screen potential, as is the lower face of each of the piezoelectric strips 6. Alternatively, the screen may be held at a suitable potential independently of the strip 4 end of the PVDF strips 6; for example the screen may be held at ground potential. The second conductive strip 8 makes electrical contact with the upper faces of each of the strips 6 and acts as a collector for the piezoelectric signals generated when the elements 6 are flexed. These signals are fed to the core of cable 24 via connector 22. When the active parts of the monitor have been assembled as described, the screening envelope is sealed. Next, an elastic (e.g. polyurethane) sheet 10 is rolled over the screening envelope and a second layer of PVC foam is then rolled over the resulting arrangement. Finally, the whole assembly is placed into a thin-walled PVC envelope.

An alternative construction to that described above is to place the screening envelope to the exterior of the two layers of foamed PVC; appropriate connections would then be made to allow the lower faces of piezoelectric strips 6 to be maintained at screen potential.

The third aspect of the invention will now be described by way of example with reference to Fig. 7 of the accompanying drawings, which shows an exploded view of a respiration probe in accordance with the invention.

Referring now to Fig. 7, a strip of piezoelectric polyvinylidene fluoride film 44 having metallised faces is folded over onto itself and, positioned therebetween, is a flat, spongy layer 55 of PVC foam. The PVDF film is about 10 microns in thickness and the foam 55 is about 1mm in thickness. The upper surface 99 of foam layer 55 carries transfer (adhesive) tape. One limb of the generally U-shaped el - ment 44 has on opposite faces thereof pieces of copper tape 88 which hold the film in contact with the c nductive elements of a co-axial cable 111. The piezoelectric element 44 is held between two layers 66 of polyurethane film each of which carries a transfer tape 77

on its inward facing surface. The dimensions of foam layer 55 should be such as to ensure that opposite limbs of piezoelectric element 44 do not make contact with one another. The whole probe assembly is sealed in a suitable envelope, e.g. of PVC film.

CLAIMS

1. A respiration monitor which is in the form of a flexible, substantially laminar pad and which comprises a plurality of strip-like elements of a piezoelectric film having a metallic coating on both faces thereof, said elements being spaced apart from one another and held between two layers of an electrically insulating material; an electrical screening arrangement for preventing or reducing the generation of spurious electrical signals in said elements; and electrical conductors for conveying piezoelectric signals generated by said elements to the exterior of the respiration monitor.

2. A respiration monitor which is in the form of a substantially laminar, flexible pad and which comprises in layerwise arrangement: (1) a first layer of foam; (2) a first transverse electrically conductive strip secured to said first layer of foam close to one edge thereof; (3) a plurality of strip-like longitudinal elements of a piezoelectric film each secured, at one of their ends, to said first electrically conductive strip and to said first layer of foam and spaced apart from one another; (4) segments of an electrically insulating tape or foil extending between adjacent elements of piezoelectric film so as to overlie the ends of said piezoelectric elements and said first electrically conductive strip and overlapping the edges of said elements of piezoelectric film; (5) a second transverse electrically conductive strip positioned so as to overlie said segments of insulating foil or tape; (6) a first electrical connector attached to said first electrically conductive strip and disposed between said first strip and one of the segments of insulating foil or tape; (7) a second electrical connector positioned between one of said segments of electrically insulating foil or tape and said second electrically conductive strip and attached to said second electrically conductive strip; (8) a screening arrangement for preventing or reducing the generation of spurious electrical signals in said piezoelectric elements (9) a second layer of foam; and (10) an envelope surr unding the other parts of the monitor, the arrangement being such that the tw layers of foam hold between them integers (2) t (7) as set forth above; and said envelope having an outlet for an electrical cable the electrically conductive cores of which are attached t a respective one of said first and s cond electrical connectors.

3. A respiration monitor in the form of a probe for attachment to the skin of a patient, which monitor comprises a piezoelectric film having electrical connections on opposed surface portions thereof, said film being held between layers of electrically insulating material.

CLAIMS

Amendments to the claims have been filed, and have the following effect:—

(a) Claims 1 to 3 above have been deleted or textually amended.

(b) New or textually amended claims have been filed as follows:—

1. A respiration monitor which is in the form of a flexible, substantially laminar pad and which comprises a piezoelectric film and electrical conductors for conveying piezoelectric signals to the exterior of the respiration monitor, characterized in that the piezoelectric film is in the form of a plurality of strip-like elements (6) of a piezoelectric film having a metallic coating on both faces thereof, said elements being spaced apart from one another and held between layers (3) of an electrically insulating material; and in that there is provided an electrical screening arrangement for preventing or reducing the generation of spurious electrical signals in said elements.

2. A respiration monitor which is in the form of a substantially laminar, flexible pad including a piezoelectric film, characterised in that the pad comprises in layerwise arrangement: (1) a first layer of foam (3); (2) a first transverse electrically conductive strip (4) secured to said first layer of foam (3) close to one edge thereof; (3) a plurality of strip-like longitudinal elements (6) of a piezoelectric film each secured, at one of their ends, to said first electrically conductive strip (4) and to said first layer of foam (3) and spaced apart from one another; (4) segments of an electrically insulating tape or foil (7) extending between adjacent elements (6) of piezoelectric film so as to overlie the ends of said piezoelectric elements and said first electrically conductive strip (4) and overlapping the edges of said elements (6) of piezoelectric film; (5) a second transverse electrically conductive strip (8) positioned so as to overlie said segments (7) of insulating foil or tape; (6) a first electrical connector (21) attached to said first electrically conductive strip (4) and disposed between said first strip and one of the segments (6) of insulating foil or tape; (7) a second electrical connector (22) positioned between one of said segments (7) of electrically insulating foil or tape and said second electrically conductive strip (8) and attached to said second electricity conductive strip; (8) a screening arrangement for preventing or reducing the generation of spurious electrical signals in said piezoelectric elements; (9) a second layer of foam; and (10) an envelope surrounding th other parts of the monitor, the arrangement being such that the two layers of f am hold b tween them integers (2) to (7) as set forth above; and said envelope having an outlet for

an electrical cable (24) the electrically conductive cores of which are attached to a respective ne of said first and second electrical connectors (21; 22).

3. A respiration monitor as claimed in claim 1 or 2, characterised in that said screening arrangement is an envelope formed of an electrically conductive material in which the piezoelectric and electrically conductive parts of the monitor are encapsulated.

4. A respiration monitor as claimed in claim 3, characterised in that said envelope is a metallised plastics envelope.

5. A respiration monitor as claimed in claim 1, 2, 3 or 4, characterised in that all of the components constituting the monitor have smooth, substantially texture-free surfaces.

6. A respiration monitor in the form of a probe for attachment to the skin of a patient, which monitor comprises a piezoelectric film having electrical connections on opposed surface portions thereof, characterised in that said film is strip-like in form and folded into a U-shaped configuration (44), both limbs of the film being held between layers of electrically insulating material (55; 66).

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X000001
July 31, 1790

The United States.

To all to whom these Presents shall come- Greeting.

Whereas Samuel Hopkins of the City of Philadelphia and State of Pensylvania hath discovered an Improvement, not known or used before such Discovery, in the making of Pot ash and Pearl ash by a new Apparatus and Process, that is to say, in the making of Pearl ash 1st by burning the raw Ashes in a Furnace; 2d by dissolving and boiling them when so burnt in Water, 3rd by drawing off and settling the ley, and 4th by boiling the ley into Salts which then are the true Pearl ash; and also in the making of Pot ash by fluxing the Pearl ash so made as aforesaid; which Operation of burning the raw Ashes in a Furnace, preparatory to their Dissolution and boiling in Water, is new, leaves little Residuum; and produces a much greater Quantity of Salt: These are therefore in pursuance of the Act, entituled "An Act to promote the Progress of useful Arts", to grant to the said Samuel Hopkins, his Heirs, Administrators and Assigns, for the Term of fourtan Years, the sole and exclusive Right and Liberty of using, and vending to others the said Discovery, of burning the raw Ashes previous to their being dissolved and boiled in Water, according to the true Intent and Meaning of the Act aforesaid. In Testimony whereof I have caused these Letters to be made patent, and the Seal of the United States to be hereunto affixed. Given under my Hand at the City of New York this thirty first Day of July in the Year of our Lord one thousand seven hundred & Ninety.

G. Washington

City of New York July 31st 1790.-

I do hereby Certify that the foregoing Letters patent were delivered to me in pursuance of the Act, entitled "An Act to promote the Progress of useful Arts"; that I have examined the same, and find them conformable to the said Act.

Edm: Randolph Attorney General for the United States.-